4.6 GEOLOGICAL RESOURCES

This section discusses potential geology issues associated with the proposed Chevron El Segundo Marine Terminal Lease Renewal Project (Project). This information outlines the environmental setting, regulatory setting, significance criteria, the potential for impacts to the facilities from various geological events (e.g., earthquakes, beach scour, liquefaction) and the significance of these impacts. This section also discusses impacts associated with alternatives to the proposed Project and projects identified in the cumulative projects analysis.

4.6.1 Environmental Setting

Topography and Bathymetry

The onshore portion of the Marine Terminal lies along the coastline of Santa Monica Bay, between the Palos Verdes Peninsula on the southeast and Ballona Creek on the northwest. The site lies within the Los Angeles Basin, a large alluvial basin characterized by relatively low relief and natural slopes, generally less than five percent. This basin is bordered on the north by the San Gabriel Mountains, on the west by the Pacific Ocean, on the south by the Santa Ana Mountains, and on the east by the convergence of the San Gabriel and Santa Ana Mountains. Three ephemeral streams provide major drainage for the basin: the Los Angeles, San Gabriel, and Santa Ana Rivers. Ballona Creek, approximately four miles (6.4 kilometers [km]) north of the site, was the outlet for the Los Angeles River prior to 1825, but it is currently a stormwater runoff channel.

The basin is a northwest trending topographic lowland plain, approximately 50 miles (80.5 km) long and 20 miles (32.1 km) wide. Topography at the Marine Terminal is nearly horizontal. Elevations at the onshore portion of the Marine Terminal range from approximately 10 to 30 feet (3.1 to 9.1 meters [m]) above mean sea level (MSL). The average slope of the onshore portion of the site is four degrees (13 feet [4.0 m] horizontal for every one foot [0.3 m] vertical).

The offshore portion of the Marine Terminal is in Santa Monica Bay. Santa Monica Bay is a semi-enclosed area characterized by a gently sloping (approximately 0.5 degrees) continental shelf, extending seaward to a break in the shelf at a depth of approximately 328 feet (99.97 m) below sea level. The shelf break marks the northward extension of the Palos Verdes uplift. The bay is landward of the Santa Monica Basin, an offshore depositional basin, the floor of which ranges from 2,625 to 2,953 feet (800 to 900 m) below sea level.

The gently sloping shelf within Santa Monica Bay is cut by two submarine canyons, Santa Monica Canyon and Redondo Canyon. The offshore portion of the Marine Terminal lies on the Santa Monica Shelf, approximately three miles (4.8 km) south of Santa Monica Canyon and approximately one mile (1.6 km) north of Redondo Canyon.

The bottom of Santa Monica Bay near the Marine Terminal moorings is essentially a uniform sloping plain with minor rises and depressions. Berth 3 is approximately 1.4 miles (2.3 km) offshore and Berth 4 is approximately 1.5 miles (2.4 km) offshore. The pipeline systems from Berths 3 and 4 are buried through the surf zone and beach, but they are exposed on the sea floor. Bathymetry in the berthing area is fairly constant. Around the groin area, bathymetry relative to mean lower low water (MLLW) is approximately 12 feet (3.7 m). Bathymetry in the area of Berths 1 and 2 (no longer operating) is approximately 32 to 39 feet (9.8 to 11.9 m). Bathymetry in the area around Berths 3 and 4 is approximately 48 to 66 feet (14.6 to 20.1 m).

Stratigraphy

The stratigraphy of the western Los Angeles Basin and the Santa Monica Basin is essentially identical. Unconsolidated and semi-consolidated Quaternary (Holocene and Pleistocene) marine and non-marine sediments overlay volcanic rocks and marine sedimentary rocks of early Pleistocene, Pliocene, and Miocene age. Metamorphic rocks of the Catalina Schist (possible Jurassic to late Cretaceous age) comprise the basement complex. This section discusses these rocks and sediments, beginning with the oldest rocks (possible Jurassic to late Cretaceous) and concluding with the youngest sediments (Holocene).

The Catalina Schist, possibly Jurassic to late Cretaceous in origin (65 to 195 million years ago), underlies much of the Los Angeles Basin and Santa Monica Shelf. Exposed along the crest of the offshore Palos Verdes uplift, south of the Palos Verdes fault, the Catalina Schist underlies the shelf at depths estimated between 0.2 and 1.5 miles (0.3 and 2.4 km) below sea level (Yerkes et al. 1965, Harding 1973).

The Miocene-age Monterey Formation overlies the Catalina Schist. In certain areas of the Los Angeles Basin, the Catalina Schist is unconformably overlaid by as much as 3.8 miles (6.1 km) of Miocene (five to 22 million years) and younger sedimentary and volcanic rocks (Yerkes et al. 1965). Thickness of the Miocene Monterey Formation underneath Santa Monica Bay ranges from 400 feet to 0.4 miles (0.14 to 0.64 km) (Osborne et al. 1980). Along the northwestern extension of the offshore Palos Verdes uplift, the Monterey Formation either outcrops or is thinly veneered by Holocene sediment (Nardin 1976, Junger and Wagner 1977, Vedder et al. 1974).

The Pliocene age (two to five million years ago) is represented by the Repetto and Pico Formations, which unconformably overlie the Monterey Formation. The lower Pliocene Repetto Formation, comprised primarily of massive siltstone, ranges in thickness from zero to 0.8 miles (0 to 1.22 km). Sedimentary rocks of the upper Pliocene Pico Formation unconformably overlie the Repetto Formation. The Pico Formation, comprised primarily of siltstone and sandstone, reaches a maximum thickness of approximately 1,000 feet (304.8 m) (Woodring et al. 1946, Yerkes et al. 1965). Pliocene sedimentary bedrock is exposed offshore along the slope near the Redondo Canyon (Junger and Wagner 1977, Vedder et al. 1974).

Due to differences between the near-shore deltaic and non-marine depositional environments present within the Los Angeles Basin and Santa Monica Shelf during Quaternary time, the presence and thickness of the representative stratigraphic units vary. Marine gravels, sands, silts, and clays comprise the overlying lower Pleistocene-age (10,000 to two million years ago) San Pedro Formation. Thickness of the San Pedro Formation onshore can reach 1,000 feet (3.408 m). In some locations within the Los Angeles Basin, the upper Pleistocene Lakewood Formation unconformably overlies the San Pedro Formation. These deposits, which consist of shallow marine sands and silts, reach a maximum thickness of approximately 150 to 250 feet (45.7 to 76.2 m). However, upper Pleistocene stratigraphy near the coastal areas consists of marine deposits of the Older Dune Sand. The Older Dune Sand comprises the El Segundo sand hills and is restricted to the coastal strip of reworked sand dunes. Recent alluvium and active sand dunes overlie the upper Pleistocene Older Dune Sand. These deposits consist of well-sorted, fine- to medium-grained sand with discontinuous lenses of silt, coarse sand, and gravel. Geotechnical investigations for the Chevron Refinery indicate that the sand deposits are generally medium-dense to very-dense silty sand and fine- to medium-grained sand (Woodward-Clyde 1993a).

Offshore Quaternary deposits in Santa Monica Bay are approximately zero to 100 feet (0 to 30.48 m) thick (Nardin 1976). The ancestral Los Angeles River dominated sediment sources of Santa Monica Bay prior to the 1930s, carrying sediment through the Ballona Gap to the Santa Monica Shelf. From the shelf, turbidity currents funneled these sediments through the Redondo and Santa Monica Canyons into the Santa

Monica and San Pedro Basins. Unconformities mark the boundaries between Pliocene and Pleistocene strata and between Pleistocene and Holocene strata.

Pleistocene deposits offshore consist of a succession of cross-bedded strata (Junger and Wagner 1977). According to Junger and Wagner, these cross-bedded strata were formed by a westward-propagating delta during the Pleistocene and may be equivalent in age to the onshore cross-bedded San Pedro Formation (Junger and Wagner 1977). Pleistocene deposits southwest of Ballona Creek and in the Manhattan Beach area consist of interlayered sediments. These light-olive sediments range from very thin to massive beds of moderate to poorly graded, fine- to medium-grained sand, and moderate to well-graded slightly granular to pebbly, and medium- to coarse-grained sand (Osborne et al. 1983).

Holocene (recent) strata typically consist of massive olive-gray, moderately to poorly graded, and very fine- to fine-grained sand, which is locally interlayered with very thin to thick beds of clayey silt and clay (Osborne et al. 1983). Silty and sandy granular gravel is also present. Thickness of these Holocene deposits ranges from zero to 100 feet (0 to 30.5 m). Due to compaction and time, Pleistocene deposits generally constitute denser, non-cohesive sediment than the overlying Holocene sediment.

Onshore Soil Contamination at the Marine Terminal

A Category B Site Assessment was conducted at the onshore components of the Marine Terminal by Radian Corporation (Radian 1986). Soil samples were collected from 22 boreholes. Groundwater elevations encountered during the investigation ranged from approximately sea level (zero feet) to 15 feet (4.6 m) above MSL. Ground surface elevations at the sample sites ranged from approximately 11 to 30 feet (3.35 to 9.14 m) above MSL. Floating product (liquid hydrocarbons) was encountered in 11 of the boreholes, with a thickness ranging from a trace (sheen) to 1.4 feet (42.67 centimeters [cm]). Evidence of liquid-phase hydrocarbons in soil was observed in 14 of the boreholes. Hydrocarbon-stained soil was observed in 20 of the 22 boring locations.

Oil and grease concentrations detected in the soil samples ranged from not detected at 50 to 40,000 milligrams per kilogram (mg/kg). Volatile organic compounds (VOC) detected in the soil samples include benzene (0.54 mg/kg), ethylbenzene (200 mg/kg), and total xylenes (120 mg/kg). Semi-volatile organic compounds detected in the soil samples include acenaphthene (three mg/kg), bis (2-Ethylhexyl) phthalate (1.6 mg/kg), chrysene (3.7 mg/kg), dibutyl phthalate (16 mg/kg), fluoranthene (2.4 mg/kg), 2-methylnaphthalene (29 mg/kg), naphthalene (12 mg/kg), phenanthrene (13 mg/kg), and pyrene (2.7 mg/kg). Concentrations for nine of the metals tested were above the established screening criteria (Radian 1986). They include: arsenic (7.8 mg/kg), copper (72 mg/kg), lead (180 mg/kg), manganese (890 mg/kg), mercury (2.8 mg/kg), molybdenum (12 mg/kg), selenium (0.89 mg/kg), silver (one mg/kg), and zinc (260 mg/kg). Concentrations identified in the enclosed parentheses are the highest value detected. Soil pH ranged from 6.3 to 9.0.

According to Chevron, past leaks at the Chevron Refinery caused the soil contamination, and no new reported leaks or spills would redefine the extent of the contamination (Goldsworthy 1994). There are no plans to remediate the soil while the Refinery is in operation. If the Chevron Refinery ceases operations, the contaminated soil will be addressed at that time. The Los Angeles Regional Water Quality Control Board, which oversees the remediation efforts at the Refinery, agrees with this course of action (Goldsworthy 1994). Consequently, there is no timeframe for the plan to remediate contaminated soils at this time.

Sediment in Santa Monica Bay

Most of the seafloor within Santa Monica Bay consists of unconsolidated sediment with silt and clay as the predominant size fraction from the 70-foot (21.3-m) isobath to the basin floor (Gardiner et al. 2003). Sandy substrates are restricted to the innermost shelf although sand is also present on Short Bank in the center of the Bay. Cobble and gravel substrates are restricted to the innermost shelf near Point Dume in the north and Palos Verdes in the south. Patches of coarse sediment are also interspersed throughout the deeper portions of the Bay, where internal bores have winnowed finer surficial sediments and exposed underlying granules that are more resistant to resuspension.

Surficial sediments near the Marine Terminal tend to be better sorted and larger in diameter than offshore sediments due to erosion, transport of sand from terrestrial areas, and strong oscillatory flows generated by shoaling surface-gravity waves. Sediments that have experienced energetic reworking tend to be better sorted with larger median grain sizes.

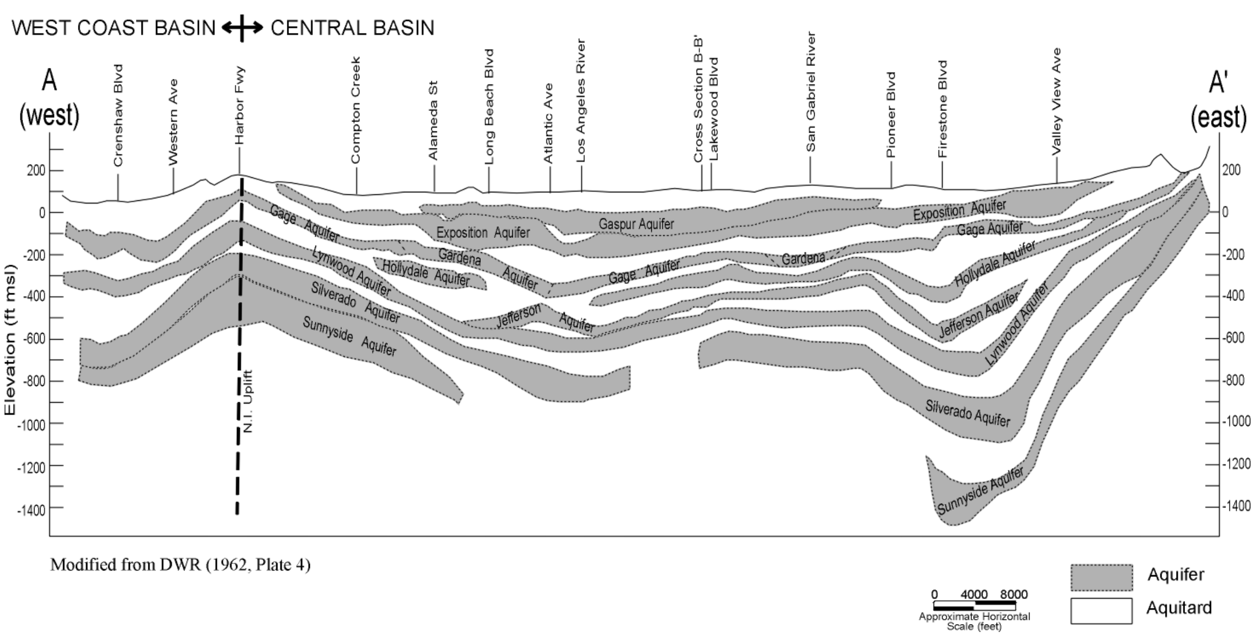
Physical characteristics of the sediment are a function of shoreline erosion, sediment transport, and settlement of particulate material out of the water column. Natural factors and human inputs influence chemical characteristics. Sediments within certain areas of Santa Monica Bay contain elevated concentrations of both organic contaminants and trace metals. They arise because of a long history of contaminant input from the adjacent, heavily populated coastline. However, the sources of contaminant input to Santa Monica Bay have changed dramatically over the last three decades, principally due to improved treatment and better source control by municipal wastewater dischargers (Bay et al. 2003).

Section 4.2, Water and Sediment Quality, discusses these physical and chemical sediment properties in further detail.

Groundwater

The Marine Terminal is located within the West Coast Groundwater Basin (Figure 4.6-1). The basin is bordered on the north by Ballona Gap, on the east by the Newport-Inglewood Fault, on the south by the Palos Verdes Hills, and on the west by Santa Monica Bay. No physical barrier exists between the freshwater aquifers underlying the onshore components of the Marine Terminal and the adjacent sea water of Santa Monica Bay. Although higher pressure in the freshwater aquifers limits sea water intrusion into the freshwater aquifers, sea water intrusion is present locally within the groundwater basin. This seawater intrusion was noted in the early 1900s, when it was progressing inland.

Figure 4.6-1
Generalized Hydrogeologic Cross Section of West Coast Basin and Central Basin



Source: WRD 2004

According to a mitigation study, sea water intrusion may have extended as far east as Aviation Boulevard, approximately 2.5 miles (4.0 km) east of the Marine Terminal (JMM 1990). As a result, the West Coast Basin Barrier Project installed a man-made barrier to limit sea water intrusion. The Project involves a series of injection wells and monitoring wells installed and maintained by the Los Angeles County Department of Public Works to control seawater intrusion into the freshwater aquifers.

Fresh water is injected into the aquifers along a line of injection wells extending southward from Los Angeles International Airport along Sepulveda Boulevard (approximately 1.8 miles [2.8 km] east of the Marine Terminal). This injection produces a groundwater mound that causes westward and eastward pressure gradients in the aquifers from the point of the injection wells, thus pushing against the invading seawater and preventing further eastward migration.

The local Quaternary shallow subsurface stratigraphy has been divided into five hydrologic units. Previous published reports on the hydrogeology of the West Coast Groundwater Basin have assigned various names to these units. This report will use the nomenclature assigned by Radian (1987) and Woodward-Clyde (1993a). The five units, from oldest to youngest, in the general area of the Marine Terminal and Refinery are the Silverado Aquifer, El Segundo Aquitard, Gage Aquifer, Manhattan Beach Formation, and the Old Dune Sand Aquifer. Due to lateral variability of the deposits, individual aquifers or aquitards may be absent locally.

The oldest hydrologic unit in the area is the Silverado Aquifer, which represents the lower Pleistocene San Pedro Formation. It is bound below by the Pico Formation, a gray silty clay aquiclude, and above by the El Segundo Aquitard. The Silverado Aquifer consists of fine- to coarse-grained sand and gravel with interbeds of pebbles. The top of the Silverado Aquifer is encountered locally at depths of approximately -60 to -75 feet (-18.3 to -22.9 m) MLLW (Radian 1987).

The El Segundo Aquitard is the uppermost unit of the lower Pleistocene San Pedro Formation. The aquitard consists of blue-gray to dark-gray laterally extensive, dense silty clay. Abundant shells and traces of wood fragments are also present within the aquitard. The aquitard underlies the transitional zone below the Old Dune Sand Aquifer at the Marine Terminal (Radian 1987). The El Segundo Aquitard is approximately 30 feet (9.1 m) thick beneath the Marine Terminal.

Hydrogeologic stratigraphy at the adjacent Refinery is different from that observed at the Marine Terminal with the presence of both the Gage Aquifer and the Manhattan

Beach Formation. The Gage Aquifer stratigraphically lies below the Manhattan Beach Formation and above the El Segundo Aquitard. It represents the upper Pleistocene Lakewood Formation. Locally, the Gage Aquifer is coarse, yellow-brown, poorly graded sand with localized layers of silt and clay. The Gage Aquifer's thickness is relatively constant, averaging 20 feet (6.10 m). It is generally present underneath the Refinery, except where the Manhattan Beach Formation and the El Segundo Aquitard merge. Based on information presented by Radian, the Gage Aquifer is not present underneath the Marine Terminal (1987).

The Manhattan Beach Formation underlies the Old Dune Sand Aquifer, approximately 0.4 miles (0.6 km) east of the Marine Terminal. Literature reports it as the Bellflower Aquitard or the unnamed Upper Pleistocene deposits (CDWR 1961, Poland et al. 1959). Locally, the Manhattan Beach Formation is a multi-layered assemblage of clay, silt, and very fine-grained sand that does not function as an aquitard in all places (Radian 1987). Therefore, aquitard is not an appropriate description of the locally present Manhattan Beach Formation. Although the term formation has a broader stratigraphic definition, its usage in referring to this locally present stratigraphic unit is appropriate (Radian 1987).

The color of the Manhattan Beach Formation clay is either tan or gray. It can be distinguished from the gray clay of the El Segundo Aquitard. The thickness and presence of the Manhattan Beach Formation is variable. It ranges from absent to approximately 55 feet (16.8 m) thick where it merges with the El Segundo Aquitard, approximately 0.4 miles (0.6 km) east of the Marine Terminal. The Manhattan Beach Formation is not present underneath the Marine Terminal (Radian 1987).

Beneath the Marine Terminal, a transition zone separates the El Segundo Aquitard from the overlying Old Dune Sand Aquifer. It is comprised of very fine-grained sand with localized amounts of silt. This transition zone ranges from 10 to 65 feet (3.0 to 19.8 m) thick.

The Old Dune Sand Aquifer includes Recent and Upper Pleistocene dune sands. Thickness of this unit ranges from approximately 55 feet (16.8 m), in the vicinity of the El Segundo Power Generating Station, to approximately 120 feet (36.6 m), just east of Vista del Mar. Drilling indicates that the Old Dune Sand consists of yellow to light brown, well-sorted, fine- to medium-grained sand, along with discontinuous lenses of silt, coarse-grained sand, and gravel (Radian 1987). Groundwater elevations in the Old Dune Sand Aquifer at the Marine Terminal range from approximately 6.9 to 7.7 feet (2.1

to 2.3 m) MLLW (Hascup 1994). The Old Dune Sand Aquifer has been contaminated with salt water and is not a drinking water source.

Seismicity

Faults are fractures or lines of weakness in the earth's crust; rocks on one side of the fault are offset relative to the same rocks on the other side of the fault. Sudden movement along a fault results in an earthquake. Southern California seismicity is dominated by the intersection of the northwest-trending San Andreas Fault System and the east-west-trending Transverse Ranges Fault System.

Several major faults are present within 60 miles (95.6 km) of the site. Faults onshore are referenced from the eastern onshore boundary of the Marine Terminal, and faults offshore are referenced from the westernmost extension of the Marine Terminal (Figure 4.6-2). Numerous smaller faults are also located throughout the Los Angeles Basin, some within a few miles of the site. Table 4.6-1 describes identified surface traces of the major active faults in the Los Angeles vicinity.

At least three fault zones, the Palos Verdes, Newport-Inglewood, and Torrance-Wilmington Fault Zones, have the potential to moderately to severely damage structures and pipelines at the Marine Terminal. Large events could occur on more distant faults in the general area, but because of the greater distance from the Project site, earthquakes generated on these faults may be considered less significant with respect to ground acceleration. Table 4.6-2 summarizes the seismicity of the faults in the Project area, while Table 4.6-3 lists large historic earthquakes recorded in the Los Angeles region.

1 **Figure 4.6-2**
2 **Major Quaternary (Active and Potentially Active) Faults and Historical Earthquake**
3 **Occurrences**
4 **1900 to 2005**

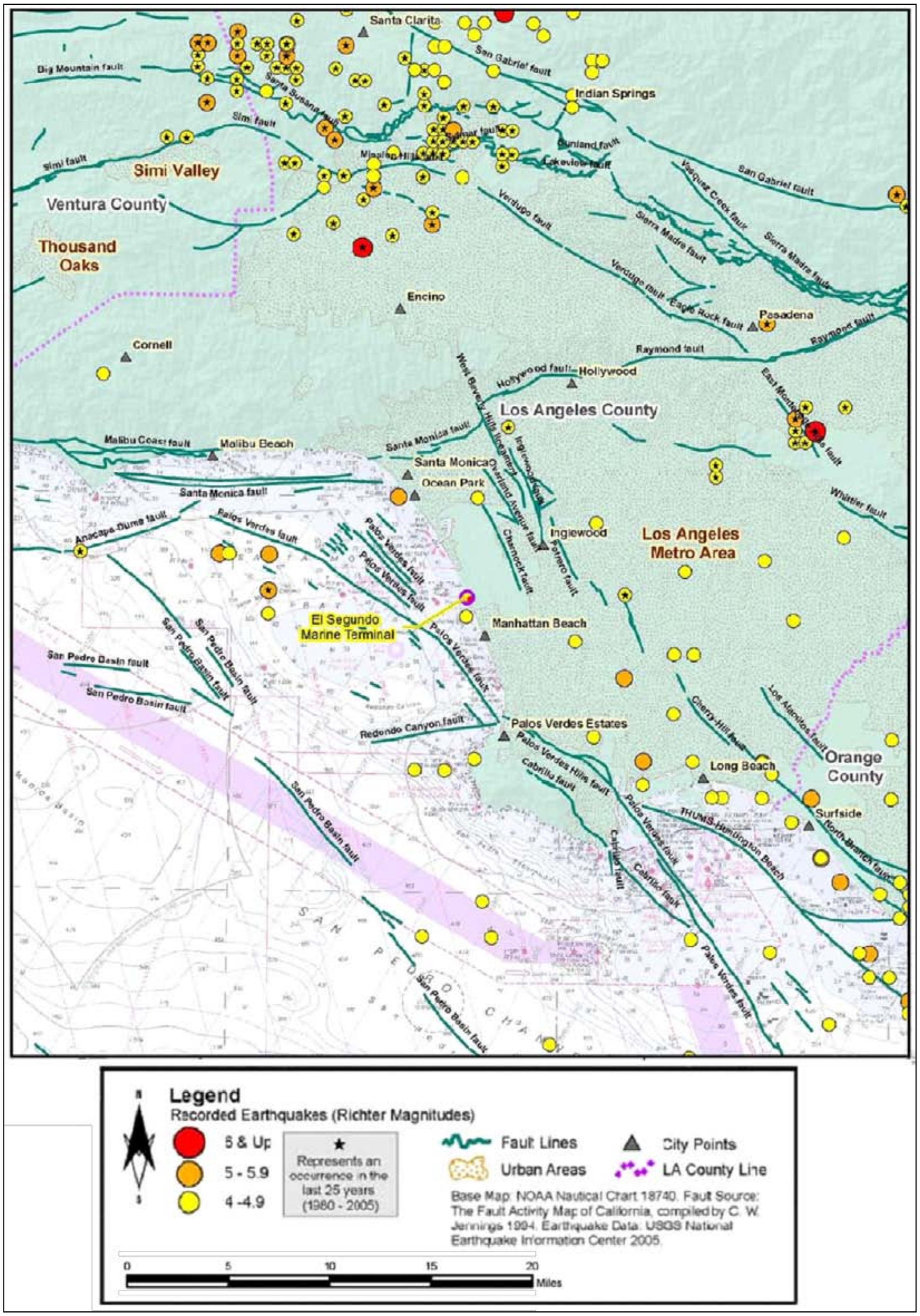


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Table 4.6-1
Fault Zone Descriptions

Fault Zone	Description
Palos Verdes	This fault zone separates the Palos Verdes Hills from the rest of the Los Angeles Basin. The zone comprises several en echelon fault strands that exhibit primarily reverse or reverse right-oblique movement. The onshore segment of the fault zone is poorly exposed due to extensive development. The offshore segment of the fault trends northwest across Santa Monica Bay and terminates at the Santa Monica Fault. Holocene and late Quaternary age activity is associated with this zone. No damaging historic earthquakes are associated with this zone, but numerous small earthquakes have been attributed to it. This fault is located approximately 2 miles (3.2 km) west (offshore) of the Marine Terminal.
Newport-Inglewood	This structural zone manifests itself as a line of positive topographic features or hills underlain by producing oil fields. Onshore, the fault zone varies between 0.5 miles and 3 miles (0.8 and 4.8 km) in width; offshore width of the zone varies between 0.5 and 2 miles (0.8 and 3.2 km). Numerous small and moderate earthquakes have been attributed to this zone, the largest was a magnitude (M) 6.3 in 1933. The Charnock and Overland Avenue Faults may represent two branches of this fault zone and are approximately 3.5 miles (5.6 km) northeast and 4.5 miles (7.2 km) northeast of the Marine Terminal, respectively.
Elysian Park and Torrance-Wilmington	These fold and thrust belts are deeply buried, low-angle reverse or thrust faults that underlie the Los Angeles Basin. The Torrance-Wilmington Thrust Zone may represent the deep-seated "master" fault thought to underlie the Newport-Inglewood Structural Zone. These faults are thought to be capable of generating earthquakes up to M 7.5. The largest earthquake attributed to these faults is the M 5.9 Whittier Narrows earthquake of 1987. The inferred surface expression of the Torrance-Wilmington Fold and Thrust Belt is located 5 to 6 miles (8.0 to 9.7 km) northeast of the Marine Terminal, while the actual fault plane passes the site.
Malibu Coast-Santa Monica-Hollywood-Raymond	This group of faults forms the southern boundary of the Transverse Ranges and is known as the Frontal Fault System. Numerous small and several moderate earthquakes have been attributed to this zone. The closest fault in this system is the Santa Monica Fault, which is approximately 10 miles (16.1 km) north of the Marine Terminal.
San Fernando-Sierra Madre	This system comprises a series of independent, arcuate fault segments in a zone as much as 0.6 miles (1.0 km) wide. Small to moderate earthquakes, including the M 6.4 1971 San Fernando earthquake, have been attributed to this fault system. This system is approximately 30 miles (48.3 km) north-northeast of the Marine Terminal.
San Jacinto	This fault zone is a northwest trending series of right-lateral faults. From the eastern San Gabriel Mountains, where it appears to merge with the San Andreas Fault Zone, the fault zone extends south for more than 190 miles (305.8 km). There have been numerous small to moderate earthquakes along this zone in historical time, and it is currently considered the primary active branch of the San Andreas Fault System. It is 60 miles (96.6 km) east of the Marine Terminal.
San Andreas	This right-lateral strike-slip fault zone is composed of numerous subparallel faults in a zone over 2 miles (3.2 km) wide. This zone extends as a continuous surface feature for about 620 miles (997.8 km), from Cape Mendocino to Banning. The latest activity ranges from late Quaternary to historical time. The fault lies approximately 51 miles (82.1 km) northeast of the Marine Terminal.
San Pedro Basin-San Diego Trough	This fault system comprises numerous Quaternary en echelon and subparallel faults. This northwest trending offshore zone extends from Santa Monica Bay south past the Mexican border. The latest activity may have been Holocene (Kennedy et al. 1980). The fault zone is approximately 15 miles (24.1 km) southwest of the Marine Terminal.

Source: Parsons 1995

Table 4.6-2
Maximum Probable and Credible Earthquakes

Fault Zone	Approximate Distance from Site, miles	Estimated Total Fault Length, miles	Maximum Magnitude of Historical Earthquakes (date)	Probable Maximum Rupture Length for Maximum Earthquake, miles	Corresponding Range of Maximum	Maximum Probable Earthquake Magnitude, Richter	Maximum Credible Earthquake Magnitude, Richter	Estimated Peak Ground Accelerations, g
Palos Verdes	2	50	5.0	18	5.0 – 6.7	5.0	6.7	0.30 / 0.56
Newport-Inglewood (Charnock Fault)	3.5	55	6.3 (1933)	27	6.6 – 7.6	6.6	7.6	0.48 / 0.63
Torrance-Wilmington	NA	37	--	NA	--	--	7.5	1.00+
Frontal Fault	10	65	6.0 (est.) (1855)	20	6.0 – 7.5	6.0	7.5	0.23 / 0.44
Whittier - Elsinore	25	120	6.7 (est.) (1892)	20	6.4 – 7.5	6.4	7.5	0.14 / 0.25
Sierra Madre – San Fernando	30	49	6.4 (1971)	18	6.6 – 7.5	6.6	7.5	0.09 / 0.22
San Andreas	51	700+	8.3+ (est.) (1857)	250	7.7 – 8.4	7.7	8.4	0.17 / 0.26
San Jacinto	60	190	7.1 (1940)	95	7.0 – 7.7	7.0	7.7	0.07 / 0.13

Source: Parsons 1995

Table 4.6-3
Large Earthquakes Recorded in the Los Angeles Harbor Area

Date	Magnitude, Richter Scale	Distance from Project, miles	Fault
January 17, 1994	6.8[a]	22	Unnamed Fault in Northridge Area
June 28, 1992	6.6[a]	95	Unnamed Fault in Big Bear Area
June 28, 1992	7.5[a]	117	Camp Rock-Emerson - Johnson Valley Faults
April 22, 1992	6.1[a]	122	Camp Rock-Emerson - Johnson Valley Faults
June 28, 1991	5.8	35	Sierra Madre Fault
October 1, 1987	5.9	23	Elysian Park Fault
February 9, 1971	6.6[a]	35	San Fernando-Sunland Fault
July 21, 1952	7.7	83	White Wolf Fault
July 1, 1941	5.9	75	Undetermined Fault in Santa Barbara Channel
March 10, 1933	6.3	34	Newport Inglewood Fault Zone
November 4, 1927	7.5	146	Undetermined Fault offshore Point Arguello
June 29, 1925	6.3	85	Undetermined Fault in Santa Barbara Channel
July 23, 1923	6.3	69	Claremont Fault (San Jacinto Fault Zone)
April 21, 1918	6.8	90	Claremont Fault (San Jacinto Fault Zone)
October 23, 1916	6.0[b]	63	Tejon Pass area (San Andreas Fault Zone, suspected)
May 15, 1910	6.0	60	Elsinore Fault
December 25, 1899	6.6[b]	94	Claremont Fault (San Jacinto Fault Zone)
April 4, 1893	6.0[b]	25	San Fernando-Santa Susana Fault
January 9, 1857	8.3[b]	166	San Andreas Fault Zone
December 8, 1812	7.0[b]	54	San Andreas Fault Zone (Newport-Inglewood Fault Zone also suspected)
December 21, 1812	7.1[b]	102	Undetermined Fault in Santa Barbara Channel
July 28, 1769	6.75[b]	27	San Fernando-Santa Susana Fault (suspected)

[a] Moment Magnitude.
[b] Estimated Magnitude
Source: Southern California Earthquake Data Center website 2010

The Newport-Inglewood, Whittier, Elsinore, Raymond, San Fernando, San Andreas, and San Jacinto Faults are considered "active," and they are designated fault-rupture hazard zones under the Alquist-Priolo Earthquake Fault Zoning Act (formerly the Special Studies Act) of 1972 (PRC 1972, Hart 1992). Under this Act, local government agencies must regulate specified projects within a fault-rupture hazard zone. The Act requires geologic investigations to locate active fault traces prior to project development and restricts human occupancy structures near active fault traces. The Project site is not located within an Alquist-Priolo Zone, and the potential for fault rupture at the site is considered low. However, active faults are typical in southern California and it is reasonable to expect a strong ground motion seismic event during the lifetime of any proposed project in the region.

An earthquake is classified by the magnitude (M) or intensity of wave movement (related to the amount of energy released), traditionally quantified using the Richter magnitude scale. Developed by Charles Richter, the Richter magnitude scale estimates the amount of energy released by a local earthquake based on the amplitude of seismic waves recorded on a Wood-Anderson Seismograph. Intended for local earthquakes, the Richter magnitude scale references the local magnitude. Magnitude is a logarithmic measure of the amplitude of seismic waves, wherein each whole number increase in Richter magnitude represents a tenfold increase in the wave magnitude generated by an earthquake. A Richter M 8.0 earthquake is, thus, not twice as large as a M 4.0 earthquake; it is 10,000 times larger (i.e., 10^4, or 10 x 10 x 10 x 10). Damage typically begins at M 5.0. In general, earthquakes M 6.0 to 6.9 are classified as moderate; those between M 7.0 and 7.9 are major, and M 8.0 and larger are classified as great.

Recently, seismologists have developed the moment magnitude scale to describe earthquakes greater than M 6.0. The moment magnitude scale is calibrated to the same scale as the Richter magnitude scale. However, it more accurately estimates the amount of energy released by a great or major earthquake because its calculation includes parameters such as the total area of the rupture surface, the amount of total slip, and the strength of the rocks involved.

The Modified Mercalli scale is a qualitative description of the intensity of ground motion at a given location generated by an earthquake (see Table 4.6-4). Computer modeling of faults indicates that the Project site could be subject to ground motion intensities ranging in Modified Mercalli values from VI to VIII+ (Evernden and Thomson 1985; Toppozada et al. 1988, 1989). The intensity of earthquake-induced ground motions can also be described using peak site ground accelerations, represented as a fraction of the acceleration of gravity.

Table 4.6-4
Modified Mercalli Intensity Scale of 1931

The Modified Mercalli scale measures the intensity of an earthquake's effects in a given locality. Values on the Modified Mercall i intensity scale range from I to XII. The most commonly used adaptation covers the range of intensity from the conditions of "I-not felt except by very few, favorably situated," to "XII-damage total, lines of sight disturbed, objects thrown into the air." While an earthquake has only one magnitude, it can have many intensities, which decrease with distance from the epicenter.

- I Not felt except by a very few under especially favorable circumstances.
- II Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
- III Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
- IV During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
- V Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.
- VI Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
- VII Everybody runs outdoors. Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
- VIII Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.
- IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
- X Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
- XI Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
- XII Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.

Source: California Division of Mines and Geology 1979.

Earthquake-induced ground motion intensity depends on earthquake magnitude, type of fault movement causing the earthquake (i.e., strike-slip, normal, or thrust), distance between the site and the epicenter, depth of the earthquake, and the nature of underlying earth materials (e.g., soils, rocks). Table 4.6-5 compares earthquake magnitude and intensity at an earthquake epicenter.

Southern California is one of the most seismically active areas in the U.S. The region has experienced at least 52 major earthquakes, M 6.0 and greater, since 1796. Sudden movements of large blocks of the earth's crust along faults generally cause regional ground motion. Great earthquakes, M 8.0 and more, like the 1857 San Andreas Fault earthquake, are rare in southern California. Nonetheless, historically two or three earthquakes of M 7.8 or greater occurred approximately every 1,000 years, corresponding to a 16 percent probability in 30 years. However, the probability of an M 6.7 or greater earthquake occurring in southern California before 2037 is 97 percent (Working Group on California Earthquake Probabilities 2007).

Table 4.6-5
Comparison of Magnitude and Intensity at an Earthquake Epicenter

Richter Magnitude	Expected Modified Mercalli Maximum Intensity	Effects and Consequences
2	I-II	Usually detected only by instruments
3	III	Felt indoors
4	IV-V	Felt by most people; slight damage
5	VI-VII	Felt by all; many frightened and run outdoors; damage minor to moderate
6	VII-VIII	Everybody runs outdoors; damage moderate to major
7	IX-X	Major damage
8	X-XII	Total and major damages

Source: Adapted from CDMG 1979

Palos Verdes Fault Zone

The Palos Verdes Fault Zone is a northwest-trending fault zone, extending from northern Santa Monica Bay to a point offshore of San Clemente. The main shear of this fault zone crosses beneath West Basin and Terminal Island in the Los Angeles Harbor, and extends to the southeast exiting the harbor near Angels Gate (USACE and LAHD 1992).

The northern most segment of the fault is located offshore, approximately two miles (3.2 km) west of the Marine Terminal. The onshore segment of this fault zone covers approximately nine miles (14.5 km) separating the Palos Verdes Hills from the rest of the Los Angeles Basin. However, due to extensive development in the area, it is poorly exposed. The majority of the Palos Verdes Fault Zone lies offshore where it is approximately 0.5 miles (0.8 km) wide, and as much as 1.2 miles (1.9 km) of vertical offset has been observed (Ziony et al. 1974).

Based on offshore data, it has been inferred that two to five moderate earthquakes during late Holocene time resulted in surface rupture along this fault zone (Fischer et al. 1987). Onshore, only late Pleistocene activity has been inferred. Although the Palos Verdes Fault is considered active, the probability of a moderate or major earthquake occurring on this fault is low compared to movements on either the San Andreas or Newport-Inglewood Faults. However, due to its proximity, the Palos Verdes Fault is capable of producing moderate to strong ground motion at the Marine Terminal.

Newport-Inglewood Structural Zone

The Newport-Inglewood Structural Zone is located about six miles northeast-east of the Marine Terminal. However, both the Charnock and Overland Avenue Faults, which may be branches of this structural zone, are located closer to the site. The Charnock and Overland Faults are located approximately 3.5 miles (5.6 km) and 4.5 miles (7.2 km) northeast of the Marine Terminal, respectively. Two vertical strands with presumed vertical offset comprise these two faults. Both faults trend northwest.

The Newport-Inglewood Structural Zone runs in a northwesterly direction from Newport Beach through Signal Hill, the Dominguez, Rosecrans, Baldwin and Cheviot Hills, and apparently terminates against the Santa Monica Fault (Yeats 1973, Barrows 1974). Some authors, including Barrows (1974), believe this fault is the northwest extension of the South Coast Offshore Fault, and possibly the Rose Canyon Fault in the San Diego area, extending over a distance of 125 miles (201.2 km). Woodford et al. (1954) have suggested as much as 0.9 miles (1.4 km) of right-lateral offset along this fault.

The impact of a large or major future earthquake along the Newport-Inglewood Structural Zone has been studied extensively (Barrows 1974; Evernden and Thomson 1985; Toppozada et al. 1988, 1989). Because the Newport-Inglewood Structural Zone is located within the greater Los Angeles metropolitan area, a major earthquake along this zone would produce intense ground motion and result in more damage and loss of life in Los Angeles than an M 8.0 earthquake on the San Andreas Fault. Due to the proximity of the Charnock and Overland Avenue Faults and the fault zone, a major earthquake could produce moderate to strong ground motion at the Marine Terminal.

Elysian Park and Torrance-Wilmington Fold and Thrust Belts

Two major fold and thrust belts have been recognized in the Los Angeles Basin. A growing body of geologic and geophysical data, supplemented by regional structural interpretations, has been used to delineate these two belts, known as the Elysian Park and Torrance-Wilmington Fold and Thrust Belts. These seismically active belts are located in areas of folding, which are not associated with strike-slip faults, but rather are caused by movement on blind, or concealed, low-angle thrust faults at depth. Geologic models illustrating these fault systems are presented by Davis et al. (1989) and Biddle (1991).

The possible surface expression of the Elysian Park Fold and Thrust Belt, the better known of these two belts, lies within 11 miles (17.7 km) of the Marine Terminal. It follows a line of hills extending from Whittier through Montebello, downtown Los Angeles, Elysian Park, the Cahuenga and Sepulveda passes, to Malibu and Point Dume (Reich 1989). This fold and thrust belt is approximately 62 miles (99.8 km) long and can be divided into at least five segments (Hauksson 1990). The geological and earthquake data alone cannot resolve if each of these large segments are underlain by one continuous thrust fault, or many small thrust faults. Both the M 5.9 Whittier Narrows earthquake of October 1, 1987, and the M 4.5 Montebello earthquake of June 12, 1989, resulted from movement on this fold and thrust belt.

The inferred surface expression of the Torrance-Wilmington Fold and Thrust Belt follows the Newport-Inglewood Structural Zone offshore from Newport Beach to Long Beach, crosses beneath the Los Angeles Harbor and the Palos Verdes Hills, and extends into Santa Monica Bay where it merges with the Elysian Park Fault to form one thrust belt that continues to the west of Point Dume (Hauksson 1990). The Marine Terminal is located within the thrust belt. This thrust belt is approximately 37 miles (59.5 km) long and can be divided into three large segments, based mostly on the boundaries of oil fields within the belt (Hauksson 1990). Like the Elysian Park Thrust Zone, whether each of the large segments consists of one large or many small thrust faults cannot be resolved based on existing data.

If several segments could rupture simultaneously, the Elysian Park and Torrance-Wilmington Fold and Thrust Belt could generate earthquakes up to M 7.5. The probability of such an earthquake occurring is unknown. An earthquake of this magnitude on the Elysian Park Fold and Thrust Belt would generate strong ground motions in the area of the Marine Terminal. Due to its proximity, the Torrance-Wilmington Fold and Thrust Belt could generate intense ground motion at the Marine

Terminal. Local peak horizontal and vertical ground accelerations experienced during an earthquake on a low-angle thrust fault could exceed 1.0 g, and could locally be much higher. Such ground accelerations would be similar to those measured during the M 6.4 1971 San Fernando earthquake (1.25 g horizontal, 0.8 g vertical), the M 7.4 1992 Landers earthquake (1.1 g horizontal, 1.2+ g vertical), and the M 6.8 1994 Northridge earthquake (1.8 g horizontal, 1.2 g vertical). A major earthquake along the Torrance-Wilmington Fold and Thrust Belt could produce damage to the proposed Project location equivalent to, or greater than, damage projected for an M 7.0 earthquake generated by the Newport-Inglewood Fault.

Tsunamis

A tsunami is an ocean wave generated by the rapid displacement of a large volume of sea water as a result of either submarine vertical faulting or large-scale submarine landslides. This sudden displacement of water sets off transoceanic waves with wavelengths of up to 125 miles and with periods ranging from five to 60 minutes. The wave reaches the shore preceded by its trough, which leads to the retreat of water from the shore as the ocean level drops. This is followed by the arrival of the crest of the wave, which can amass on the shore as bores or surges in shallow water or as the rising and lowering of the surface waters in deeper water, such as in a harbor area. These ocean waves, also known as seismic sea waves, may travel thousands of miles, reach heights over 40 feet (12.2 m), and cause extensive damage to unprotected coastal areas. As has been shown historically and most recently by the December, 2004 Indian Ocean Tsunami, the potential for loss of human life from such an event can be great if the tsunami occurs in a populated area.

During historical times, coastal California has experienced numerous tsunamis of both local and distant origin. Crescent city in northern California received extensive damage from a tsunami generated by the 1964 Alaska earthquake (M 9.2). Recorded measurement of the largest wave (crest to trough) following this event was approximately 6.5 feet (2.0 m) at Santa Monica Bay (McCulloch 1985). The most damaging tsunami in southern California occurred after the 1960 Chilean earthquake (M 9.4), when wave heights up to approximately 8.9 feet were recorded in Santa Monica Bay and more than $1 million in damages were incurred (McCulloch 1985).

The likelihood of locally generated tsunamis and their potential impact on the California coastline is a topic of several fairly recent studies (e.g., Borrero et al. 2000, Borrero et al. 2004). The research predicts larger tsunami run-ups from near-shore events, such as offshore earthquakes or submarine landslides occurring within close proximity to the

California coastline. In addition to being potentially larger than a farfield event, a locally generated tsunami may have a travel time of only a few minutes, offering less of a warning and posing a direct threat to nearshore facilities. For example, simulations of the Catalina Fault, which lies directly beneath Catalina Island approximately 22 miles (35.4 km) from the Project site, predicted run-up heights up to 13.2 feet (six m) arriving in Santa Monica Bay in approximately 20 minutes.

Locally, the 1927 Point Arguello earthquake generated a tsunami of 6.5 feet in the Los Angeles region (Ziony and Yerkes 1985). An earthquake, located within or near the Santa Barbara Channel, occurred in 1812 (M 7 to 7.5) and generated a tsunami. Evidence indicates run-up of approximately 10 feet at Gaviota.

Predictive models for distantly generated tsunamis indicate that wave heights of approximately 9.8 feet (3.0 m) are exceeded on the average of once every 500 years at Santa Monica Bay (McCulloch 1985). The potential for locally generated tsunamis caused by sea floor faulting in the Santa Barbara Channel may have run-up heights of 13 to 20 feet (4.0 to 6.1 m). Wave run-up heights generated by earthquakes along strike-slip faults may range from 6.5 to 9.8 feet (2.0 to 3.0 m) (McCulloch 1985).

Seismically Induced Liquefaction and Lateral Spreading Potential

Liquefaction, a process by which water-saturated sediment suddenly loses strength, commonly accompanies strong ground motions generated by earthquakes. During an extended period of ground shaking or dynamic loading, porewater pressures increase and the ground is temporarily altered from a solid to a liquid state. Liquefaction is most likely to occur in unconsolidated, granular sediments that are water saturated less than 30 feet (9.1 m) below ground surface (Tinsley et al. 1985). As described above, earthquake-induced ground motion is dependent upon earthquake magnitude, type of fault movement, distance from the epicenter, depth of an earthquake, and the nature of the earth materials underlying the site.

The severity of ground shaking at a particular location is also affected by the depth-to-groundwater. Shaking intensity decreases approximately one intensity unit with an increase in depth to groundwater from zero to 30 feet (9.1 m) (Evernden and Thomson 1985). Measured depths to groundwater at the Marine Terminal range from 14.9 to 20.9 feet (4.5 to 6.4 m) below ground surface (Radian 1994). Depths to groundwater decrease to approximately five feet below ground surface toward the western onshore perimeter of the Marine Terminal (Radian 1986). Sediments at both the onshore and offshore portions of the site consist of unconsolidated sand.

The highest susceptibility for liquefaction is associated with cohesionless granular materials and shallow (zero to 10 feet) depths of groundwater (Tinsley et al. 1985). Due to the shallow depth to groundwater at the onshore portion of the site, the saturated submarine conditions present at the berths, and the young age (Holocene) of the sediments, the potential for liquefaction at the site is high. Along the shoreline, the potential for liquefaction has been designated as very high (Tinsley, et al. 1985).

Lateral spreading is the lateral displacement of surficial sediments as a result of liquefaction in a subsurface layer. It is most likely to occur where loose, water-saturated sandy sedimentary deposits are situated near a free face, such as storm drain channels, sloughs, and waterfront areas (Tinsley and Youd 1985). Since the Marine Terminal is underlain by unconsolidated sediments with a very high liquefaction potential along the shoreline, the potential for lateral spreading is present at those locations where sediments are situated near a free face.

If liquefaction occurs at depth, and slopes are too gentle to permit lateral displacement, ground oscillation is likely to occur. Overlying sediments may oscillate on liquefied sediments underneath, causing damage to structures and sub-grade facilities. Ground oscillation due to subsurface liquefaction is considered unlikely at the Marine Terminal because sediments underlying the Old Dune Sand have increased clay content and are relatively more cohesive.

Seismically Induced Landslide Potential

Slope instability is related to slope gradient, soil or rock type, consolidation or cementation of the rock, and the extent of fracturing within the rock. Landsliding can be seismically induced, resulting from extended periods of groundshaking and high ground accelerations. Improper grading and excessive rainfall or irrigation can also increase the susceptibility of landsliding. Generally, slopes of 10 degrees or more are subject to seismically induced landsliding. Slopes onshore and offshore are nearly flat, four degrees and 0.5 degrees, respectively. Therefore, the probability of seismically induced landsliding at the Marine Terminal is considered low.

Settlement and Subsidence

Settlement of the ground surface occurs as a result of compaction of underlying unconsolidated sediments. Differential settlement, the uneven and localized settling of structures or the ground surface, is most common in uncompacted soils, unconsolidated alluvial material, and improperly constructed artificial fill. Ground subsidence is caused by decreasing subsurface pressure and is typically associated with the rapid removal of large volumes of groundwater, natural gas, or oil. It is also a secondary hazard associated with seismic activity.

Although unconsolidated sediments, primarily sand, are present at the Marine Terminal, other conditions for potential settlement are not present. Subsidence due to removal of large volumes of oil or natural gas, such as in the Wilmington Oil Field, is not a factor in the area near the Marine Terminal (Leeson 1994). Rapid removal of large quantities of groundwater is also not likely, even though Chevron currently operates a groundwater recovery remediation system. Groundwater, once separated from the LHC, is re-injected into the aquifer, thereby limiting the potential for local subsidence due to groundwater extraction. In addition, groundwater extraction on a regional scale is currently not occurring within the underlying Gage and Silverado Aquifers due to salt water intrusion. Due to the West Coast Basin Barrier Project, groundwater injection is occurring.

4.6.2 Regulatory Setting

Federal

The Uniform Building Code (UBC) defines different regions of the United States and ranks them according to their seismic hazard potential. There are four categories of these regions, designated as Seismic Zones 1 through 4, with Zone 1 having the least seismic potential and Zone 4 having the highest seismic potential. The project area is located within Seismic Zone 4; accordingly, any future development would be required to comply with all design standards applicable to Seismic Zone 4.

State

California Building Code

The State of California provides a minimum standard for building design through the California Building Code (CBC), which is based on the UBC, but has been modified for California conditions. The CBC is selectively adopted by local jurisdictions, based on local conditions.

Chapter 23 of the CBC contains specific requirements for seismic safety. Chapter 29 of the CBC regulates excavation, foundations, and retaining walls. Chapter 33 of the CBC contains specific requirements pertaining to site demolition, excavation, and construction to protect people and property from hazards associated with excavation cave-ins and falling debris or construction materials. Chapter 70 of the CBC regulates grading activities, including drainage and erosion control. Construction activities are subject to occupational safety standards for excavation, shoring, and trenching, as specified in the State of California Division of Occupational Safety and Health (commonly called Cal/OSHA) regulations (Title 8 of the California Code of Regulations) and in Section A33 of the CBC.

California State Lands Commission - Marine Oil Terminal Engineering and Maintenance Standards

The Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) were approved by the California Building Standards Commission on January 19, 2005, and are now part of the CBC. These standards apply to all existing and new marine oil terminals in California, and include criteria for inspection, structural analysis and design, mooring and berthing, geotechnical considerations, fire, piping, mechanical and electrical systems. The purpose of MOTEMS is to establish minimum engineering, inspection and maintenance criteria for marine oil terminals in order to prevent oil spills and to protect public health, safety and the environment.

The Alquist-Priolo Special Studies Zones Act of 1972

The criteria most commonly used to estimate fault activity in California are described in this act, which addresses only surface fault-rupture hazards. The legislative guidelines to determine fault activity status are based on the age of the youngest geologic unit offset by the fault. An active fault is described by the California Geological Survey (CGS) (formerly the California Division of Mines and Geology [CDMG]) as a fault that has "had surface displacement within Holocene time (about the last 11,000 years)." A potentially active fault is defined as "any fault that showed evidence of surface displacement during Quaternary time (last 1.6 million years)." This legislation prohibits the construction of buildings used for human occupancy on active and potentially active surface faults. However, only those potentially active faults that have a relatively high potential for ground rupture are identified as fault zones. Therefore, not all potentially active faults are zoned under the Alquist-Priolo Earthquake Fault Zone, as designated by the State of California.

The Seismic Hazards Mapping Act

These regulations were promulgated for the purpose of promoting public safety by protecting against the effects of strong ground shaking, liquefaction, landslides, other ground failures, or other hazards caused by earthquakes. Special Publication 117, Guidelines for Evaluating and Mitigating Seismic Hazards in California (CDMG 1997), constitutes the guidelines for evaluating seismic hazards other than surface fault-rupture, and for recommending mitigation measures as required by Public Resources Code (PRC) Section 2695(a). However, to date the CGS has not zoned offshore California under the Seismic Hazard Mapping Act. Therefore, this act does not apply to this Project.

California Coastal Act

The California Coastal Air Act (Coastal Act) of 1976 created the California Coastal Commission (CCC) and six area offices, which are charged with the responsibility of granting development permits for coastal projects and for determining consistency between Federal actions and the State's coastal management program. Also in 1976, the State legislature created the California State Coastal Conservancy to take steps to preserve, enhance, and restore coastal resources and to address issues that regulation alone cannot resolve. The Coastal Act created a unique partnership between the State (acting through the CCC) and local government to manage the conservation and development of coastal resources through a comprehensive planning and regulatory program. The CCC uses the Coastal Act policies as standards in its coastal development permit decisions and for the review of local coastal programs, which are prepared by local governments. Among many issues, the local coastal programs require protection against loss of life and property from coastal hazards, including geologic hazards.

4.6.3 Significance Criteria

Impacts to the geological environment of the proposed Project would be considered significant if:

- Unique geologic features, such as paleontological resources, or geologic features of unusual scientific value for study or interpretation would be disturbed or otherwise adversely affected;
- Known mineral (gas or petroleum) resources would be rendered inaccessible;
- Geologic processes, such as landsliding or erosion, would be triggered or accelerated; or
- Substantial alteration of topography or ground surface relief, beyond that resulting from natural erosion and deposition.

Impacts of the following geologic hazards on the proposed Project would be considered significant if they occur:

- Earthquake-induced ground shaking occurs, which is capable of causing settlement or surface cracks at the site and attendant damage to structures, or of causing a substantial loss of use, or of exposing the public to substantial risk or injury;
- Ground rupture due to an earthquake at the site and attendant damage to structures and improvements causing a substantial loss of use;
- Earthquake induced ground shaking capable of causing liquefaction and settlement at the site and attendant damage to structures and improvements causing a substantial loss of use; or
- Local and distant earthquake induced tsunamis causing flooding at the site and attendant damage to structures and improvements causing substantial loss of use.

4.6.4 Impact Analysis and Mitigation Measures

The potential impacts from the proposed Project involving Geological Resources are presented in this section. Significant geologic impacts of the proposed Project are primarily related to the susceptibility of project facilities to damage from earthquakes and from the secondary effects of earth movement. Potential impacts are analyzed in detail below for every potential geological resource and the influence of the proposed Project on those resources.

Although the facilities and the potential impacts due to seismic events are existing, the potential for increased throughout at the Marine Terminal associated with the proposed project in the form of increased vessel calls and increased time loading and unloading vessels, would create an incremental increase in the potential severity of a seismic event.

Topography, Bathymetry, and Stratigraphy

Underwater pipeline replacement and onshore maintenance would not require major grading or earth moving activities during the 30-year lease period. However, bathymetric changes over time in the vicinity of the existing pipelines could give rise to unsupported spans which, given and earthquake or other stress producing situation along the pipeline, could produce a pipeline failure leading to a spill.

According to the CSLC, the last bathymetry survey was conducted in October 2007. CLSC has given Chevron El Segundo an exemption from conducting annual bathymetry surveys, which have been historically conduced to ensure that the depth was not decreasing, thereby giving rise to potential vessel groundings. Chevron has been allowed to survey the berths every three years. The exemption was granted because the present berths three (3) and four (4), were described as actually getting deeper. The previous bathymetry survey which was conducted in October 2007 reveals only a few isolated areas of these berths had actually lost sediments from the ocean bottom due to propeller scouring action of the vessels. These areas are identified as several isolated twelve foot depressions below the surrounding seafloor with one at berth 4, which is described as near the pipeline end manifold (PLEM), and has grown larger in size with the PLEM located reportedly on the slope of this depression. There is a possibility that this propeller scour may undermine the pipeline end manifold causing an undetermined amount of stress on this pipeline termination point. Additional bathymetric monitoring is recommended in Section 4.1, System Safety and Reliability, impact SSR-2 and mitigation measure SSR-2f. Therefore, there would be no additional impact.

Soils at the Marine Terminal (Onshore)

The proposed Project may impact soils at the onshore portion of the site. Potential activities during the proposed Project may require limited excavation of soil at the site to access the pipelines. Soil excavated may be contaminated with petroleum hydrocarbons and require remediation. In addition, potentially contaminated soil would be left in-place during the lease term. Since the potential areas that may be excavated would be small and contaminated soil volumes would also be small and easily removed, impacts associated with soil at the site would be less than significant.

Groundwater

Shallow groundwater at the site has been impacted by previous activities. Remediation of this groundwater contamination is currently underway. In addition, deeper groundwater aquifers are not used in the area. Therefore, no new adverse impacts to groundwater are anticipated from implementation of the proposed Project.

Seismicity

Impact GEO–1: Rupture of Facilities from Earthquake Motion

Oil spills from ruptures of pipelines and other facilities could occur as a result of earthquake motion (Potentially Significant, Class I).

Earthquake-related hazards, such as seismicity and faulting, cannot be avoided in the southern California region. Based on the 2007 Working Group on California Earthquake Probabilities data, there is 99.7 percent probability that southern California will experience a M 6.7 or greater earthquake during the next 30 years. An earthquake of this magnitude on one of the known faults previously discussed may cause extensive damage to the Marine Terminal. A moderate to great earthquake along one of the faults in the Project vicinity would result in strong to intense ground motions at the site, including high ground accelerations beyond design specifications for facilities. Ruptures of pipelines and other components of the facility could occur and result in spilled petroleum products. Further, the underwater pipelines are unburied on the sea floor in water depths of greater than 12 feet (3.6 m) in compliance with U.S. Bureau of Ocean Energy Management, Regulation, and Enforcement West Coast guidelines and requirements for areas subject to seismic activity.

Seismic hazards associated with major or great earthquakes in southern California are an unavoidable aspect of living in the region. A moderate to great earthquake along one of the faults in the Project vicinity would result in strong to intense ground motions at the site, including high ground accelerations beyond design specifications for facilities. Ruptures of pipelines and other facilities could occur and result in spilled crude oil or petroleum products. The frequency of these events would increase under the proposed project as the amount of material loaded and unloaded, and therefore the time to load/unload the materials at the Marine Terminal, could increase under the proposed Project. These impacts would be potentially significant (Class I) and would remain significant after the implementation of the mitigation measures.

Mitigation Measures

GEO-1a. Implement Site-Specific Geotechnical and Seismic Evaluation Results. The Applicant shall complete a site-specific geotechnical and seismic-hazard evaluation for any new facilities or pipeline routes including faulting, ground shaking, liquefaction hazards, landslides and slope stability issues. The Applicant shall submit certified copies of these reports to California State Lands Commission for review and approval 60 days prior to the start of any construction and maintain an ongoing process during construction (as applicable). The Applicant shall implement all recommendations from the Geotechnical and Seismic studies as directed by California State Lands Commission. In addition, any new engineered structures, including pipeline alignment and profile drawings, buildings, other structures, other appurtenances and associated facilities, shall be designed, signed, and stamped by California registered professionals certified to perform such activities in their jurisdiction such as Civil, Structural, Geotechnical, Electrical and Mechanical Engineering.

GEO-1b. Seismic Resistant Design. The Applicant shall perform seismic evaluation and design for all existing facilities or pipelines and employ current industry seismic design guidelines including but not limited to: Guidelines for the Design of Buried Steel Pipe by American Lifeline Alliance (2001), Guidelines for the Seismic Design and Assessment of Natural Gas and Liquid Hydrocarbon Pipelines by Pipeline PRCI (2004), and California State Lands Commission Marine Oil Terminal Engineering and Maintenance Standards for seismic resistant design of the pipeline. The seismic evaluation of existing facilities shall be conducted in accordance with the Local Emergency Planning Committee Region 1 Guidance for CalARP Seismic Assessments including a walkthrough by a qualified seismic engineer. In addition, post-event inspections must follow the Marine Oil Terminal Engineering and Maintenance Standards guidelines. This evaluation and design shall be conducted within one year of lease renewal and reports submitted to CSLC annually thereafter.

GEO-1c. Seismic Inspection. During the term of the 30-year lease, the operator shall cease associated pipeline operations and inspect all project-related pipelines and storage tanks following any seismic event in the region (Los Angeles County and offshore waters of the Santa Monica Bay and southern Channel Islands) that exceeds a ground acceleration of 13 percent of gravity (0.13 g). The operator shall report the findings of such inspection to the California State Lands Commission, the city of El Segundo, and the County of Los Angeles. The operator shall not reinstate operations of the Marine Terminal and associated pipelines within the city of El Segundo until authorized by the California State Lands Commission.

Rationale for Mitigation

By incorporating site-specific earthquake-resistant design into newly engineered facilities, and performing inspections after all great seismic activity, impacts from future seismic activity can be reduced.

Residual Impacts

It is economically infeasible to construct facilities that are completely resistant to damage from the possible high ground accelerations associated with a major or great earthquake in southern California. Therefore, potential adverse impacts are unavoidable and would remain significant (Class I).

Impact GEO–2: Oil Spills From Tsunami Wave Damage

Increased wave activity during a tsunami condition could create hazards for vessels in the berths and result in spilled crude oil or petroleum products during vessel unloading procedures (Potentially Significant, Class I).

A major to great earthquake within the Pacific Rim or a large-scale submarine landslide in the Project vicinity could result in a tsunami. Based on the elevation of onshore facilities and the estimated run-up from tsunamis, it is anticipated that tsunamis of distant origin would not result in an adverse impact. However, a tsunami of local origin could inundate onshore facilities, causing flooding and potential damage to these facilities. This would result in an adverse impact. Since the probability of a local earthquake generating a tsunami exceeding surface elevations at the site is considered low, this potential adverse impact to onsite facilities is not considered significant.

Offshore facilities would be exposed to tsunamis of both local and distant origin. The offshore facilities are expected to withstand a significant wave height of 15 feet (4.6 m) and a maximum individual wave height of 23 feet (7.0 m). The offshore facilities are therefore expected to withstand the presently predicted tsunami waves. However, if the berths, pipelines, or vessels are damaged while unloading, petroleum products could spill. The frequency of these events would increase under the proposed project as the amount of material loaded and unloaded, and therefore the time to load and unload the materials at the Marine Terminal, could increase under the proposed Project. This would be a significant impact (Class I) and would remain significant after the implementation of **MM GEO-2**.

Mitigation Measures

GEO-2. Tsunami Alert. Tsunami response training and procedures shall be developed to assure that construction and operations personnel will be prepared to act in the event of a large seismic event. As part of the overall emergency response planning for this project, the procedures shall include immediate evacuation requirements in the event that a large seismic event is felt that could affect the proposed Project site such that all precautions can be made in the event of a local tsunami. This shall include the departure of all vessels in berth or in the area. These procedures shall be submitted within one year of the lease renewal and reports submitted to CSLC annually thereafter.

Rationale for Mitigation

Establishment of standard procedures and training for a large seismic event would provide a quick response time for all vessels in berth to depart and mobile equipment to be secured in the event of a tsunami.

Residual Impacts

Immobile equipment onshore would not be able to be secured in the event of a tsunami warning. Therefore, the impact would remain significant (Class I).

Impact GEO–3: Oil Spills as a Result of Liquefaction

Liquefaction could cause settling of the ground surface and associated facilities, causing damage to pipelines and other facilities, which would result in an oil spill (Potentially Significant, Class I).

An extended duration of ground shaking associated with a moderate to major earthquake in the area could induce liquefaction at the site. Liquefaction at the site could result in settling of the ground surface and associated facilities, causing damage to pipelines and other facilities at the site. However, both offshore and onshore petroleum pipelines are designed to allow for some movement, settlement, and spanning without causing damage to the pipeline. A steel pipeline is a continuous welded structure with substantial tensile strength, generally in excess of that required to contain internal pressure. Depending upon the length and location affected, the pipeline can withstand loss of some support (caused by soil liquefaction, for example) without being overstressed or damaged. In addition, the Marine Terminal does not have any tall structures. Tall structures can be subject to damage in an earthquake if liquefaction occurs because of higher overturning movement and loss of soil support. Minor settlement could be possible, but the design of these facilities accommodates minor settlement, and no significant damage is anticipated. In the unlikely event of damage to facilities, this would possibly result in spills of crude oil or petroleum products. The frequency of these events would increase under the proposed project as the amount of material loaded and unloaded, and therefore the time to load/unload the materials at the Marine Terminal, could increase under the proposed Project. This would be a potentially significant impact (Class I) and would remain significant after the implementation of **MM GEO-1a** through **GEO-1c**.

Rationale for Mitigation

By incorporating earthquake-resistant design into newly engineered facilities, and by following recommended mitigation measures, impacts from future liquefaction can be reduced.

Residual Impacts

It is economically infeasible to construct facilities that are completely resistant to damage from liquefaction associated with a major or great earthquake in southern California. Therefore, potential adverse impacts are unavoidable and would remain significant.

Table 4.6-6
Summary of Significant Geological Resources Impacts and Mitigation Measures
Proposed Project

Impact	Mitigation Measures
GEO-1: Rupture Of Facilities From Earthquake Motion	**GEO-1a**. Implement Site-Specific Geotechnical and Seismic Studies Results **GEO-1b**. Seismic Resistant Design **GEO-1c**. Seismic Inspection
GEO-2: Oil Spills From Tsunami Wave Damage	**GEO-2**: Tsunami Alert
GEO-3: Oil Spills as a Result Of Liquefaction	**GEO-1a** through **GEO-1c**

4.6.5 Impacts of Alternatives

No Project Alternative

Under this alternative, the Marine Terminal would be dismantled and all facilities removed. Since the facility would not be in operation, it would no longer be exposed to impacts associated with seismic or other geological hazards. No adverse impacts would occur.

If excavation were needed to remove facilities, contaminated soils could be encountered and the potential for erosion would exist. Since it is likely that agency-approved erosion control measures and contaminated soil removal measures would be included in the dismantling plan, impacts would not be significant.

Removal of pipelines could expose the underlying seabed to erosion. Currently, portions of the offshore pipelines are buried, while the remaining sections lie atop the sea floor. Consequently, the removal of the buried pipelines could potentially account for a significant amount of sediment transport or lead to erosion. See Section 4.2, Water and Sediment Quality.

CBM Relocation in State Waters for Crude Only

Under the Conventional Buoy Mooring (CBM) Relocation Alternative in State Waters for Crude Oil Only, the Marine Terminal would continue to operate, but Berth 4 would be relocated farther offshore in state waters. Under this alternative the Berth 4 CBM and navigational moorings would be relocated into deeper water approximately two miles (3.2 km) offshore for crude oil offloading only. This would allow very large crude carriers (VLCC) to moor at the CBM and offload the crude without lightering operations. This location, approximately two miles (3.2 km) offshore, is the maximum practical distance to relocate the CBM system because of water depth, impact on operations, and several other factors. With the implementation of this alternative, Impacts **GEO-2** and **GEO-3** identified for the proposed Project would remain the same. These impacts include tsunami hazards and liquefaction damage.

Since the Palos Verdes Fault Zone is approximately two miles (3.2 km) offshore, these moorings would be located near, and possibly seaward of, identified traces of this fault. If pipelines cross active or potentially active traces of the Palos Verdes Fault Zone, they could be subject to rupture resulting from subsea surface displacement along these fault traces. This represents a significant adverse impact (Class I) more substantial than the proposed Project and it would remain significant after the implementation of **MM GEO-1a** through **GEO-1c.**

Rationale for Mitigation

The potential for pipe rupture as a result of earthquake-induced offset on the Palos Verdes Fault could be reduced if design features were incorporated into the pipelines to make them sufficiently flexible to withstand earthquakes.

Residual Impacts

The impacts could not be avoided unless the pipelines were shortened to a sufficient distance away from all potential fault traces. Since it is expected that not all fault traces in the area have been identified to date, additional studies would be needed to determine the proper distance that the pipeline could be extended without being impacted by the fault zone. Impacts **GEO-1**, **GEO-2**, and **GEO-3** would remain significant after mitigation.

SPM Replacement in State Waters for Crude Only

Under this alternative, the Marine Terminal would continue to operate, but the existing Berth 4 CBM would be decommissioned and replaced with a single point mooring (SPM) located farther from shore in State waters. An SPM allows a ship to weathervane around the buoy to find a stable position, and thereby minimizing the environmental impact on the system since the moored ship can readily adjust into prevailing weather without affecting offloading operations. With this alternative, Impacts **GEO-2** and **GEO-3** identified for the proposed Project would remain the same. These impacts include tsunami hazards and liquefaction damage.

Since the Palos Verdes Fault Zone is approximately two miles (3.2 km) offshore, these moorings would be located seaward of identified traces of this fault. Pipelines would cross active or potentially active traces of the Palos Verdes Fault Zone, and they could be subject to rupture resulting from subsea surface displacement along these fault traces. This represents a significant adverse impact at the same level as the CBM alternative impact.

VLCC Use of Pier 400

Under this alternative, the Marine Terminal would continue to operate, but a portion of the Marine Terminal operation would utilize the recently permitted Pier 400 facility. The only Marine Terminal traffic displaced under this alternative would be the VLCC traffic that currently transports light crude oil to the Refinery by lightering offshore and using smaller tankers to call on the Marine Terminal. Under this alternative, all exports of refined product and imports of heavier crude oil would continue using the existing Marine Terminal. Impacts and mitigation would be the same as those for the proposed Project.

This alternative may require modifying and constructing pipelines between the POLA and the Marine Terminal. Consequently, design and construction could introduce seismic concerns, similar to Impact **GEO-1**. Therefore, even after implementing **MM GEO-1a** through **GEO-1c**, impacts would be similar to the proposed project.

4.6.6 Cumulative Projects Impact Analysis

Impacts of seismic events on Project facilities would not have cumulative effects on other projects, since the Marine Terminal is dedicated to serving the Refinery, and is not physically located adjacent to other facilities that might be affected by adverse effects on the Marine Terminal. Because no other projects are located in the vicinity that would cause other geological or soils impacts, no significant cumulative impacts to or from earth resource and geologic hazards are anticipated.